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Project acronym: **SEAT**
Project title: **S**mart t**E**chnologies for stress free **A**ir **T**ravel

# SIXTH FRAMEWORK PROGRAMME
# PRIORITY [4]
# AERONAUTICS AND SPACE

# SPECIFIC TARGETED RESEARCH PROJECT

***Deliverable:***

***Title:***
***Publishable Activity Report***
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|---|---|---|
| **Dissemination Level** | | |
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| **PP** | Restricted to other programme participants (including the Commission Services) | |
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| **CO** | Confidential, only for members of the consortium (including the Commission Services) | |

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## *Project summary*

Passenger comfort is clearly a main factor in user's acceptance of transportation systems. An individual's reaction to a vehicle environment depends not only on the physical inputs but also on the characteristics of the individual. The findings of a number of passengers' surveys and comfort related research indicate that there is not a universal optimal setting for comfort related parameters in a plane. Hence individual passengers are always likely to have certain conflicting requirements as perception for comfort is affected by a variety of factors - gender and ethnicity among the most important ones. SEAT promotes a radically new concept where passenger comfort is taken to a new level. The SEAT system developed has smart responsive seats and interior environment with the capability of detecting physiological changes of passenger's condition in real time. This in turn is analysed and appropriate adjustments such as temperature control, air ventilation, seat parameters are put in place. The entire approach has been to create an environment that responds to the individual requirements and desires and is not centrally controlled or manually adjusted. The system is based on advanced technologies and systems developed by the partners as breakthrough research developments or other advanced technologies. A prototype of this new system was demonstrated to the public at the end of the project.

The main SEAT achievements of SEAT include:

- Development of a system that suppresses noise overall, as well as for each passenger.
- Development of active/passive vibration reduction.
- Development technology allowing healthier cabin environment including temperature, pressure, airflow and humidity.
- Development of a functional prototype of the "SEAT" system.

Major innovations within the SEAT project are:

- Innovative wearable technologies for physiological modelling.
- Use of intelligent textiles with built-in sensors and active dampening facilities.
- Development of advanced modelling tools that allow simulating and assessing the effect of different "smart solutions" for noise control.
- Use of technologies developed by the partners in the area of avionics, on-board entertainment, noise control, smart textiles, wearable monitoring for aircraft cabin.

## *Participant List*

| Partic. Role* | Participant name | Participant short name | Country |
|---|---|---|---|
| CO | Imperial College London | IC | UK |
| CR | Acústica y Telecomunicaciones, S.L | ACU | SP |
| CR | Asociación de Investigación de la Industria Textil | AIT | SP |
| CR | Antecuir S.L. | AN | SP |
| CR | Czech Technical University | CTU | CZ |
| CR | Eidgenoessische Technische Hochschule Zuerich | ETHZ | CH |
| CR | INSITITUTO TECNOLOGICO DEL CALZADO Y CONEXAS | INE | SP |
| CR | Queen Mary and Westfield College | QM | UK |
| CR | StarLab | ST | SP |
| CR | Technische Universiteit Eindhoven | TUE | NED |
| CR | Thales | TH | FR |
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## *Introduction*

The SEAT project focused on upstream questions of an integrated system that i) creates a healthier and more comfortable cabin environment through reduction of noise and vibrations and user specific climatic controls and ii) provides a high level of customer focused services that simulate home and office environment.
The need for a novel approach to passenger comfort originates in the fact that travel has become a global activity that is not confined to any geographic area, social or ethnic group. As a consequence airlines need to address frequently conflicting requirements and in a centrally controlled environment, the “lowest common denominator” approach is the only viable one. This is frequently utilised at the lower price end, while the high end of the market normally opts for more services and features that would satisfy these usually more demanding customers. However, examples such as MiniPod show that the current thinking is focused on the travelling executive requirements but do not necessarily address the contextual needs of different group, require a lot of space and many of its costly facilities are rarely used. Users have very little time to study different features and are frequently reluctant to do so. Hence it is important that such features are not manually controlled but are part of an integrated system that adapts to the passenger’s needs. This project aims to develop such new radical approach through integration of cabin systems with multi media features and will strongly draw on preceding European projects where some of the partners have been already involved.

The SEAT project was focused on:

- Creation of a “smart seat” that adapts the climatic characteristic to the passenger physiological status;
- integrated physiological monitoring system with health alert options;
- development of a system for active/passive vibration dampening incorporating smart textiles;
- development of interactive entertainment; and
- development of fully integrated cabin passenger services.

The main SEAT objectives were defined as follows:

- To develop a system that suppresses noise overall, as well as for each passenger.
- To develop novel approach to active/passive vibration reduction incorporating smart technologies and textiles in particular.
- To develop technology allowing healthier cabin environment including temperature, pressure, airflow and humidity.
- To develop on-board systems that will enable office-like and home-like services.
- To develop a functional prototype of the “SEAT” system that will be an important stage of a development of e-cabin.

The work plan devised to ensure that all the key objectives of the project were included in 5 technical workpackages, i.e.

1. Physiological monitoring of passengers systems
2. Smart seat
3. Noise and vibration attenuation
4. Interactive and integrated entertainment
5. Development of integrated adaptable system

In the next section the activities within the above 5 work packages are described.
Further details can be found in the publication listed at the end of this report and from project deliverables.

### *Physiological monitoring of passengers systems*

Travel stress is best detected by measurement of appropriate physiological variables such as heart rate, blood pressure and other physiological variables. Some of these variables could

also be used for health monitoring of passengers belonging to high risk groups such as passengers' suffering from heart condition, pregnant women etc. It is also well known that such measurement normally correlate very well with the level of satisfaction.
WP1 was devoted to development of appropriate physiological model for assessment of passengers comfort and corresponding measuring systems some of which were installed in the seat (temperature, pressure and humidity sensors, breath frequency measurement installed in seatbelt and others worn by the passengers in the form of a health monitoring kit – EDA and ECG sensors worn on the fingers). These devices monitor the level of comfort in terms of posture (pressure distribution) and thermal comfort provide input for analysis of the physiological responses to given settings. The model is used to analyse the derived data and subsequently devise a strategy if alteration of the controllable (temperature and posture) parameters is required. The required interventions are relayed to the control system that will implement appropriate parameters alterations or directly to passenger or crew. In addition to the direct comfort related to the physiological but more to the individual perception and psychological reactions of the passenger to the travel conditions. The s[specifically developed wearable devices allow to counteract psychological stress.

**Thermal comfort model**
A model was developed by QM for monitoring the thermal comfort level of passengers during a flight. A diagram of the model is presented below.

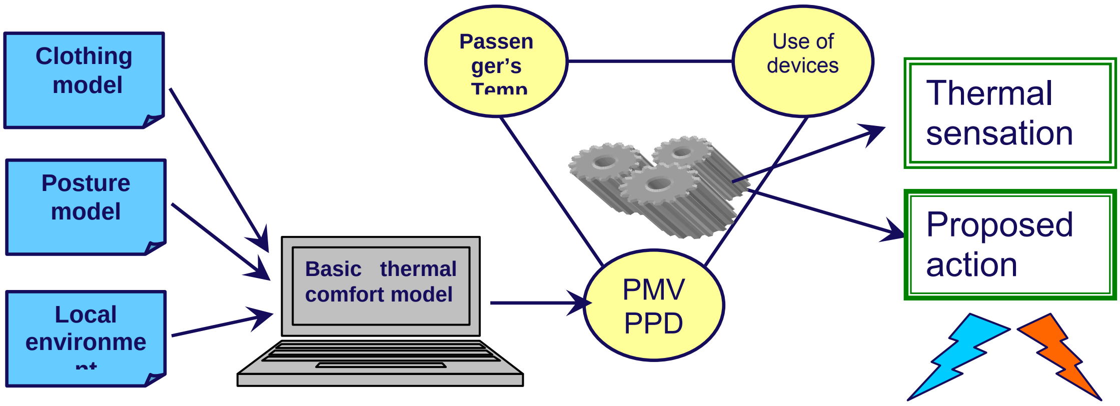


Figure 1: Sketch of thermal comfort model

The inputs for this model are:
- Environmental T and H
- T in back and thigh of the passenger
- Face temperature
- Use of the cabin air supply system by passenger
- Standards (ISO 7726, 7730, 8996, 9920 and 11079)
- Activity, provided by the posture model

The final outputs are:
- General setting
    - Optimal welcome cabin temperature
- Individual adjustments
    - Personalized thermal sensation
    - Proposed action
        - Increase temperature
        - Maintain temperature
        - Reduce temperature
    - Personalized optimal cabin temperature

The thermal comfort model is based on three independent modules: a "basic comfort level module" (based on statistics), "passenger's temperature module" and "use of manual controls module". Each of those modules is explained below. Finally, partial outputs from each of the modules are compared and weighted in the “decision module” to obtain the final assessment by the model

**Passenger’s temperature module**

This module personalises the comfort level monitoring as direct temperature measurements are taken from the passengers. Those include 2 temperature measurements of the back of the passenger, one temperature measurement of the left tight of the passenger and 16 values of temperature in the area of the passenger’s face.

The main achievements of this module include:

- Identification of the clothing insulation of the passenger
- Monitoring the face temperature of the passenger
- Estimate the core temperature of the passenger
- Identify abnormal face temperature as indicative of local thermal discomfort

**Use of manual controls module**

Feedback from the passenger to the actual climate control made by the comfort system by checking the use that the passenger does of his/her personal air conditioning system. The main achievements are:

- Obtain/analyse possible feedback from the passenger regarding the cabin temperature control he/she is subjected to.
- Identify the passenger’s preference in terms of cabin temperature

**Decision module**

This module combines in a complex way the results provided by the three previous models to generate a final output. It also assesses the model itself to identify erroneous responses, so it guarantees the best control of temperature for each individual passenger. It does checks such as:

- Is the evolution of the passenger’s temperature the one predicted by the model?
- Does the passenger do any action against the decision taken by the model?

The model learns from the experience of each of the passengers, becoming more efficient with the time.

**Monitoring system**

The prototype of the physical system used by QM during the project for tests and experiments is presented in Figure 2. For this prototype, sensors were provided by INESCOP and cushions and integration were done by AITEX.

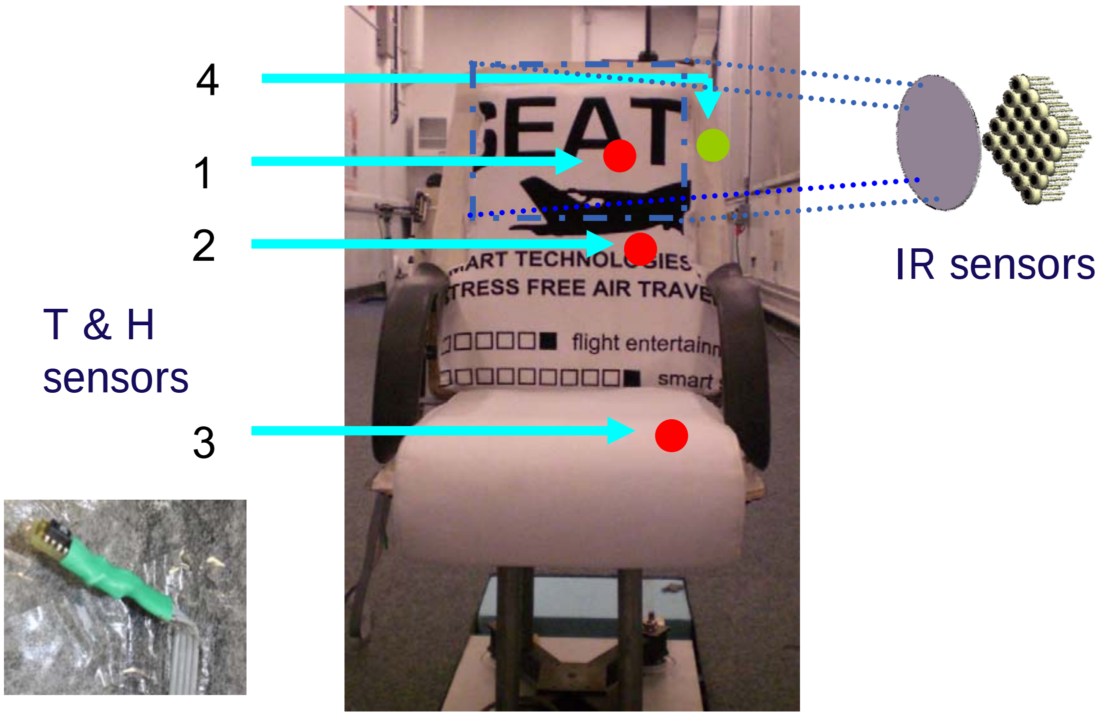


Figure 2: Prototype of the physical system for comfort monitoring

Studies undertaken included:

- Effect of room temperature step changes on the passenger
- Effect of prolonged inactivity
- Identification of normal core and body temperature during the flight
- Identification of the clothing insulation of the passengers

**Measuring Techniques for Physiological Parameters**

ETHZ has developed appropriate sensor techniques to measure breathing rate, electrocardiography (ECG), electro dermal activity (EDA), ambient temperature, relative humidity and movements of the passenger. Beside the design of measuring devices appropriate for an airplane, also the trade-off between sensor comfort and signal quality were investigated during typical airplane activities. In addition, ETHZ has shown how such a sensor framework can be use to automatically detect mental stress and emotions which are related to fear of flight.

For measuring the breathing rate, two measuring techniques were investigated. As a first option a small resistive stretch sensor incorporated into the safety-belt was used. Secondly, a proposal for detecting the breathing rate from a coil that is integrated into the seat was simulated.

In order to acquire the Electro Dermal Activity (EDA) of a passenger to measure arousal and mental stress, ETHZ has developed a wearable device. This so called Emotion-Board consists of two finger straps connected to an arm band. The attached board contains electronics for amplification and pre-processing of the physiological signal and a Bluetooth wireless data transmission module. In addition to the EDA signal, the Emotion-Board can also measure ambient temperature and relative humidity. The evaluation of the Emotion-Board was performed at ETH Zurich. An extensive experiment has shown a statistical correlation between the EDA signal and a startle event.

Based on the design of the Emotion-Board, ETHZ developed two new sensor boards:

1. The PhysioBoard that measures physiological signals (ECG, EDA, respiration, and finger temperature) for analyzing the health and mental state of the passenger.
2. The Data Acquisition Board (DAB) that records ambient sound for activity

recognition.

Figure 3 shows an overview of the integrated system for physiological monitoring which was developed by ETHZ.

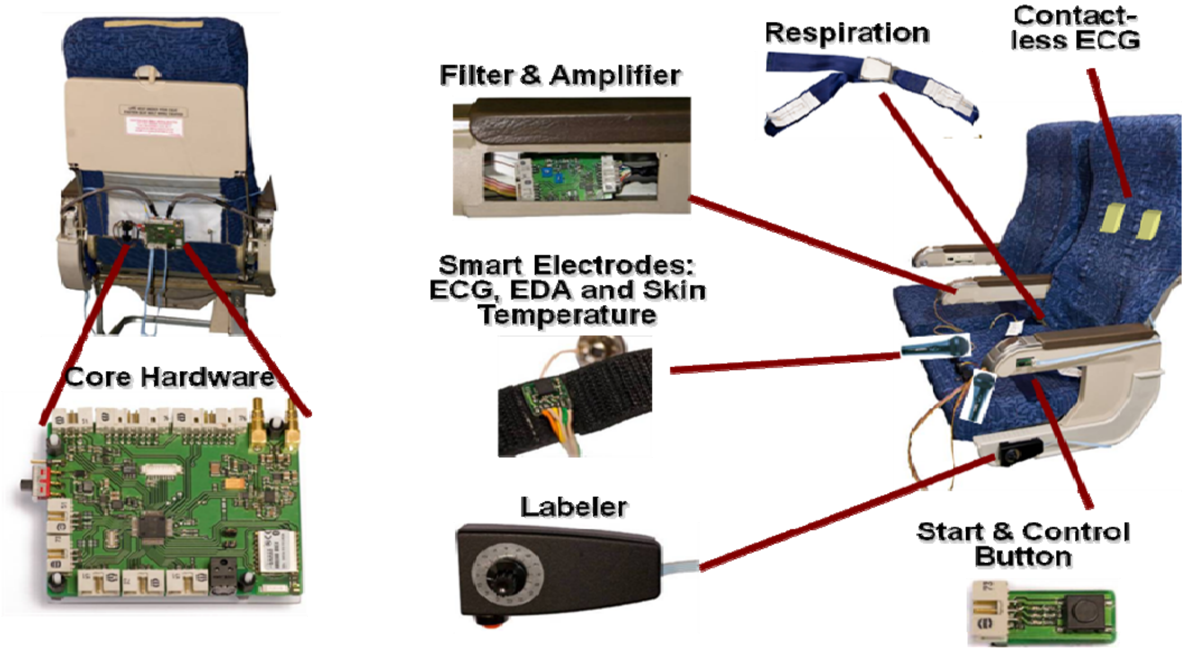


Figure 3: ETHZ Sensors integrated into the airplane seat

The respiration is measured by a small strain-sensor integrated into the safety-belt whereas the other physiological signals are measured using smart finger electrodes. Each electrode is equipped with small accelerometers in order to measure the movements of the hands and fingers since movement is an important information source for automatic artifact compensation. ETHZ developed methods for artifact detection through sensor fusion and conducted a feasibility study, in which normal passenger activities were performed.

Another challenge to be solved when using unobtrusive sensors is the data loss due to artifacts. Data loss is a frequent phenomenon in practical applications using several physiological signals. Discarding the whole data instance if only a part is corrupted results in a substantial loss of data. To address this problem, ETHZ has investigated methods for handling missing data using classifier fusion. The five emotions amusement, anger, contentment, neutral and sadness were elicited in 20 subjects by films while six physiological signals (ECG, EMG, EOG, EDA, respiration and finger temperature) were recorded (see Figure 4).

Figure 4: Subject watching movies for emotion elicitation

Results show that classifier fusion significantly increases the recognition accuracy in comparison to single classifiers by up to 16.3%.
In order to detect emotion speech is an interesting signal. Based on existing work from psychology, speech data were recorded and analyzed aiming at recognizing human emotions in a seat environment. Another issue tackled by ETHZ is the automatic detection of stress. According to representative surveys, 30 to 50 percent of all passengers feel uneasy in airplanes and some passengers experience severe anxiety attacks. Fear of flight is therefore quite a common experience which can be measured using physiological signals. However, it is difficult to elicit fear of flight on the ground. ETHZ has therefore performed a laboratory stress experiment in collaboration with psychologists.

### *WP 2: Smart seat*

Seat technology for aircrafts has improved considerably over the last decade. More and more attention is paid to the adaptability of the seats and their adjustability. However, this is frequently achieved through increase in space requirements and weight that is not desirable for aircraft manufacturers The natural extension of this technology is to introduce active adjustability that allows the seat settings and controls to be linked with passenger responses such as increase of temperature if passenger is falling asleep. In effect the seat reaction prevents the passenger feel discomfort. In addition the seat is linked with a system for active entertainment, providing an appropriate level of exercise. It is anticipated that the role of the seat will increase considerably with the introduction of smart technology and that the seat will act as a central point for both physiological monitoring and entertainment aide of comfort provision.

The smart seat developed under this WP contains a system which monitors the posture of the passenger and also the environmental parameters such as temperature and humidity, as well as the physiological parameters like corporal temperature, breathing rhythm and ECG. Furthermore, a conceptual model for regulating the temperature and humidity of the microclimate of each passenger has been developed, achieving all the goals proposed at the beginning of the project. Achievements for WP2 include:

- Identification and selection of appropriate upholstery and padding materials including smart textiles.
- Integration of the embedded sensors into the upholstery.
- Developing a model for monitoring of temperature and humidity taking into consideration ambient factors and time variations.
- Developing of closed loop control algorithm based on physiological monitoring characteristics and model established ranges.
- Identification of humidity ventilation control within appropriate seat design.
- Design of Pressure and temperature sensors.
- Humidity sensors and appropriate measurement.

Advanced structures of active materials for seats was also be studied in order to provide to the passenger active seats which could change their response to external stimulus (pressure, temperature, magnetic field) by changing their hardness, absorption of high frequencies (see figure 5).

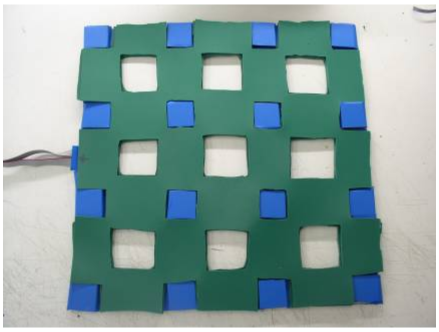

Figure 5: Sensor placement in the seat.

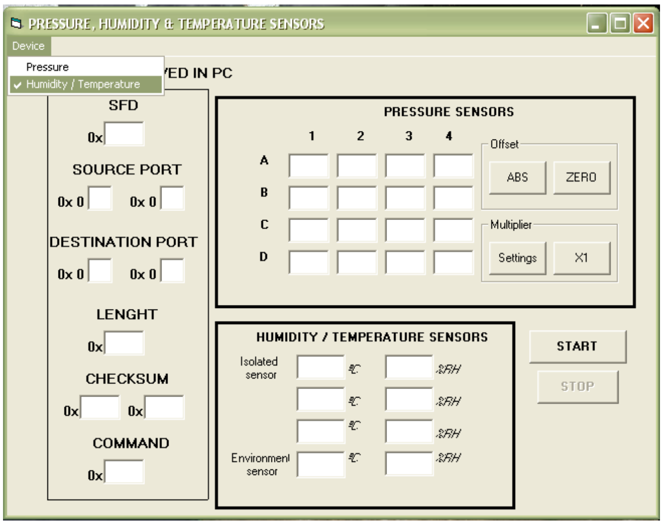


Figure 6: Software interface

As in the case of the thermographic device described for WP1, software has been developed. This software was used for data evaluation by the responsible partners in this area framed in this project. In the user interface of the program can display data from pressure sensors, those relating to humidity and temperature as well as data pertaining to the communications protocol established for this application (see figure 6).

**Humidity Control**

CTU developed a novel arrangement of personalized air distribution in airliner cabin with local air humidification has been proposed and verified by means of a FLUENT CFD program using the RNG $k - \varepsilon$ model and by laboratory mock-up experiments. The FLUENT models were developed not only for the single seat but also for cabin sectors with six and twelve seats to compare the single-seat pattern of air flow with those in the whole cabin interior section. The CFD models have revealed the possibility of designing a personalized air distribution towards the breathing area of each passenger. Even thought the passengers are supplied by conditioned fresh air via personal ventilation, which reduces considerably the risk of breathing contaminated air, around 65 % of cabin air is still provided by central ventilation. This is considerable economical advantage compared to the cabin ventilation systems fully supplied by outside air.

Although the idea of the personalized air supply to each of the passengers is not completely new, the proposed ventilation arrangement is original. Next to the supply nozzle, it also includes an exhaust nozzle in order to remove the considerable portion of used (contaminated) air from the passenger area. Just due to this newly involved component the presented arrangement is capable to constitute a closed microenvironment pocket over each of the seats. In this way the personalized air supply prevents each seated passenger from undesirable sharing the breathed air with his/her neighbours and this helps him/her to be more protected against possible air transferable infections during the flight. Nevertheless the possibility of separating the single seat environment from the other has been not only found out by means of the CFD models of cabin air circulation. The CTU group succeeded in verifying the closed stream effect on a laboratory mock-up of the seat ventilation. The turbulence of the flow in the vicinity of passenger's head observed in the laboratory experiments is harmless due to low level of air velocity, it can even be judged as advantage of the personalized air supply. It is to emphasize that all this flow can be provided from the fresh outside air despite one third of the cabin air supply is still re-circulated. Let us also remark the temperature sensitivity of the stream contours. The supply air is to be maintained necessarily at temperature sufficiently lower than that in the cabin interior. This is the prerequisite for directing the air flow from the supply towards the exhaust nozzle and for the consequent separation of the particular personalized air pocket from the other ones.

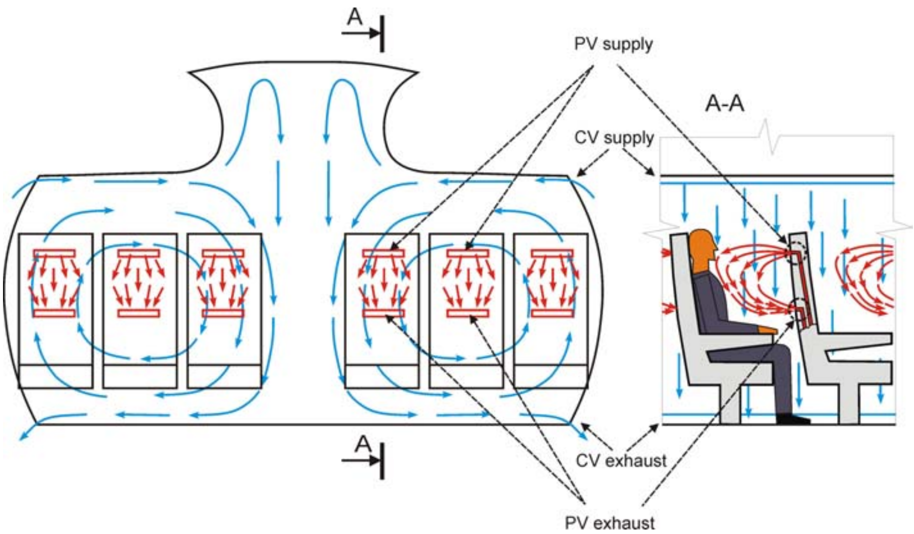


Figure 7: Proposed modification of the cabin ventilation system; blue flow streams - re-circulated air provided by central ventilation (CV) system via classical mixing principle, red flow streams - fresh and humidified air provided by personalised ventilation (PV) to the local area of each seat.

A personalized nozzle set-up was considered on the back of each seat as shown in Fig. 8.

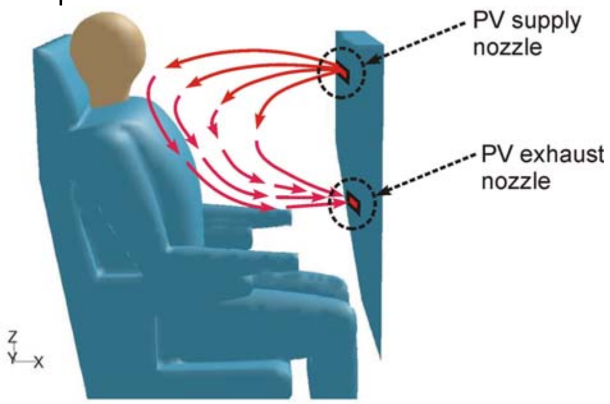


Figure 8: Scheme and geometric model of the PV set-up of the seat

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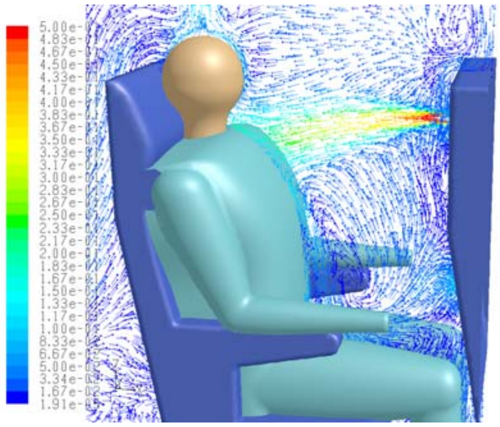

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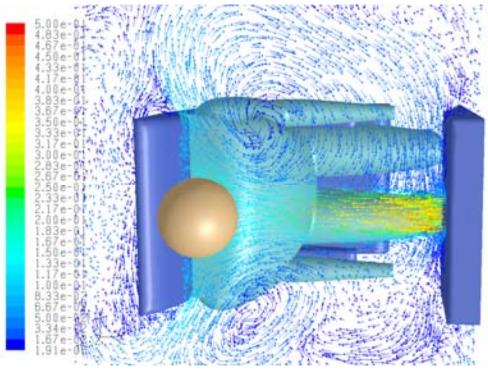


Figure 9: Air velocity vectors coloured by velocity magnitude (Tm= 30.3 °C)

In order to test the potential of the PV system to form a closed microenvironment pocket in the passenger area, an experimental set-up has been built which is in Figs. 10 and 11. The simplified model of the seat with a seated passenger and the back of the seat ahead has been built from the aluminium profiles, acrylic sheets and polystyrene foam. As can be seen in Fig. 10, both the supply and exhaust nozzles are fixed in the back of the seat ahead. The nozzles are connected by pipe-lines with ventilators. Via the ventilators, both supply and exhaust flow rates can be controlled independently. As needed for stabilizing the microenvironment pocket in the seat area, air for the supply nozzle is cooled down by about 3°C compared to the temperature of ambient air. In order to visualize the flow patterns in the seat area, a jet with visualization particles has been connected to the supply nozzle pipe. The results of the experiments with conditions given in Table 1 are shown in Figs. 11 to 13.

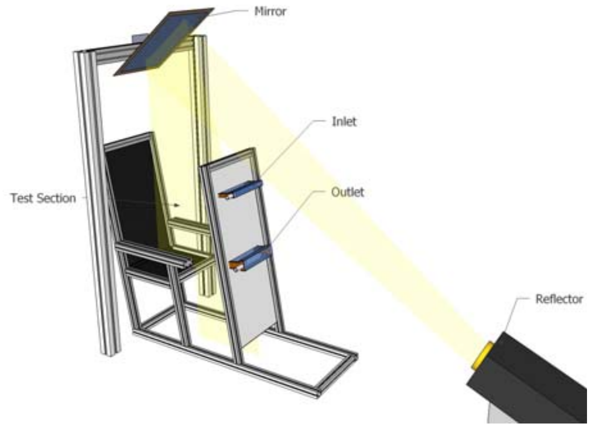



Figure 10 The experimental set-up for validation of the personalised ventilation

| | Personalized supply |
|---|---|
| Supply airflow rate [l/s per person] | 2.5 |
| Exhaust airflow rate [l/s per person] | 2.5 |
| Supply airflow temperature [°C] | 20.9 |
| External air temperature | 23.4 |

Table 1. Conditions of the experimental verification of PV system

In Fig. 12 the steady state airflow distribution in the seat area is visualized by SAFEX fog. As can clearly be seen from both side and front views, and in agreement with CFD models, the microenvironment pocket is constituted in the seat area. The passenger's breathing area is efficiently supplied by air from the supply nozzle. It can be estimated from the SAFEX fog pattern that supply nozzle airflow would provide efficient shielding of the passenger's breathing zone from the air from CV system too.

Fig. 10 Left - laboratory set-up of single seat personalized ventilation system, right – detail of the pair of nozzles built in the laboratory seat set-up.

The results of air velocity measurement close to the manikin surface are shown in Fig. 12. The velocity distribution has been measured by a PIV method with helium bubbles. As can be seen, the air velocity in the vicinity of manikin's surface does not exceed the comfort limit 0.2 m/s.

To sum up, in the same way as CFD models, the experiments have also proved the possibility to form a local environment pocket in the passenger's area. Besides, based on general matching of CFD and experimental results, it can be concluded that the used CFD methodology provides credible results and sufficiently corresponds with the measurements on the real set-up. Upon this experience the CFD model is extended to modelling the air circulation in a whole cabin sector.

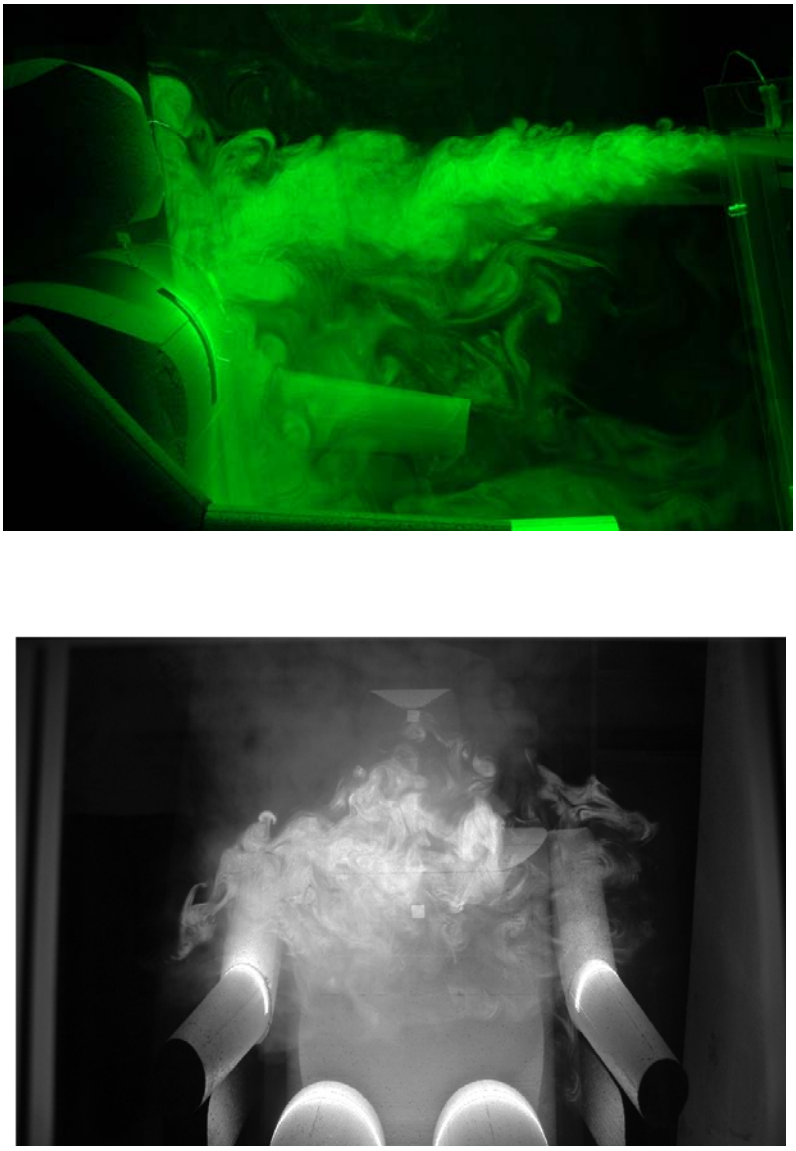


Figure 12: Airflow distribution in the seat area visualized by SAFEX fog

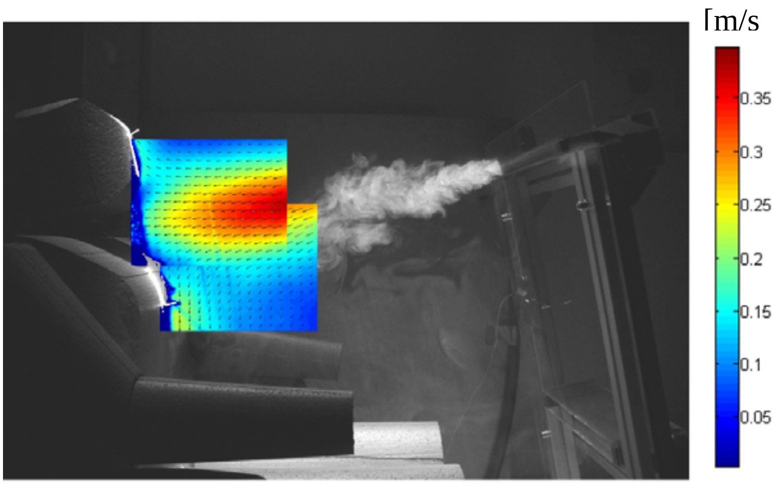



Figure 13 Velocity vectors and contours of velocity magnitude measured close to the manikin surface using PIV method with helium bubbles.

In the second stage, CFD models of the personalized ventilation system are used to design the local circulation around the seat. It has been proved on the single seat circulation models and experiments that the proposed ventilation design with properly adjusted nozzles and air velocities can supply individually the passenger with fresh and satisfactorily humidified air. Model results in Figs 14-16 demonstrate how the local zones with increased relative humidity are provided by PV. On the other hand, in Fig. 14 one can see how the air flow patterns of CV system slightly disturb the air flow in the local personalized air flow within the seat space and causes a certain mixing of PV and CP air. However, the breath intake is not influenced by this mixing. Moreover, as can be seen in Fig. 14, the humidity distribution in the cabin is close to the ideal case. The increased level of humidity is concentrated in the breathing zones of passengers, while the level of RH in remaining space of the cabin is kept low. Thus, the proposed ventilation system can be considered relatively safe with respect to the risk of humidity condensation in the cabin shell. The water consumption for this ventilation set-up is 0.08 l/hour/passenger, ie, 160 l of water for 200 passengers onboard the 10 hour flight.

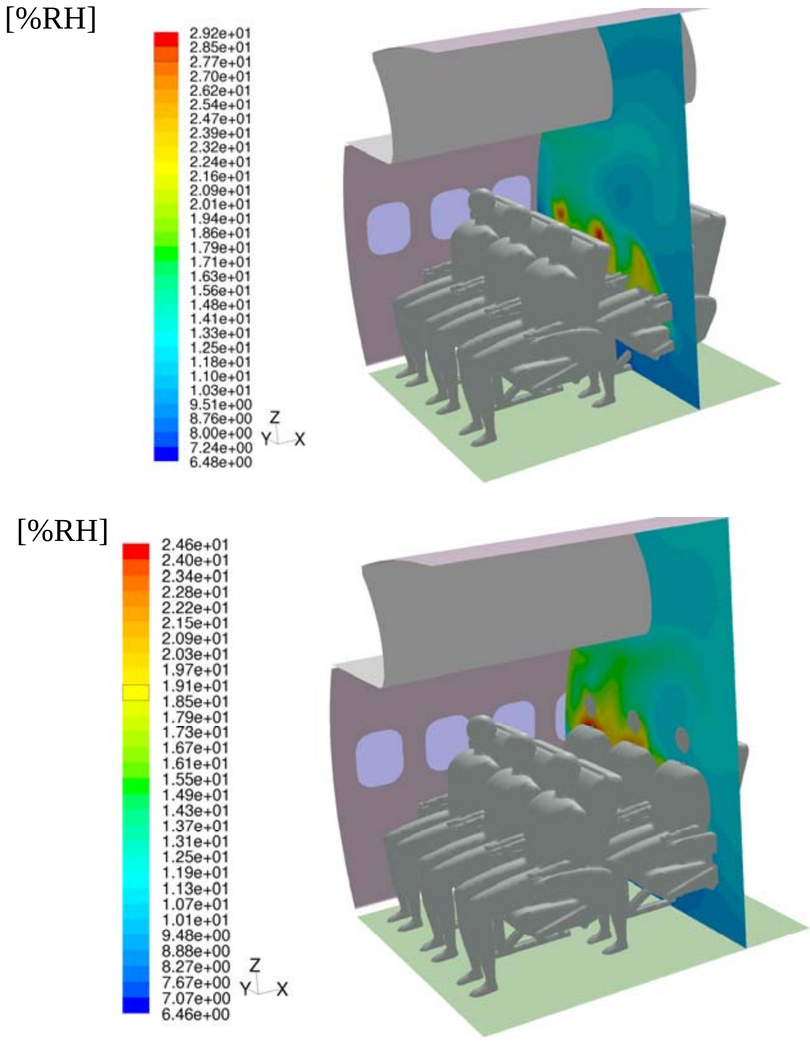



Figure 14: Distribution of the relative humidity in the seat area controlled by the personalized humidified-air distribution system

[%RH]

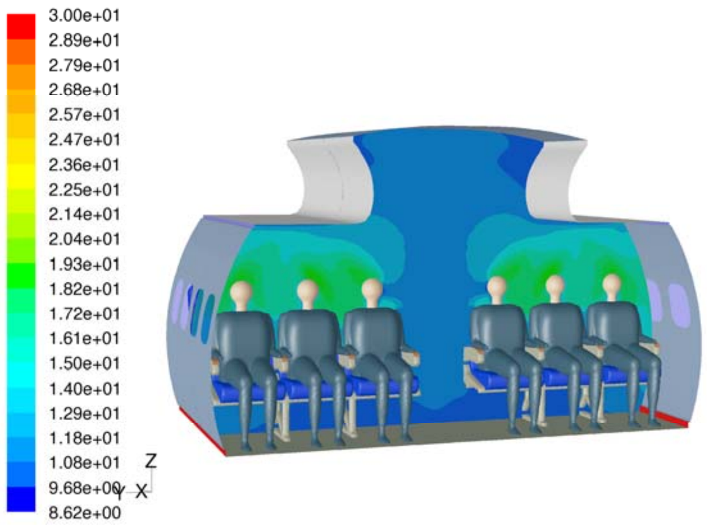



Figure 15: Relative humidity distribution resulting from the CFD model for the designed personalized humidification

[%RH]

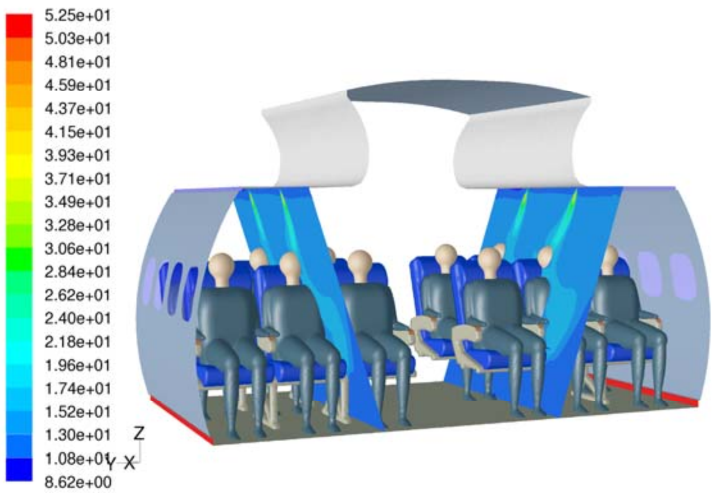



Figure 18: Humidified-air distribution system by means of individual overhead nozzles

## *Noise and vibration attenuation*

Modern aircrafts are very stable and more quite than their predecessors. However noise remains a major irritating factor for the passengers. The noise comes from three main sources – aircraft engine and vibrations, other passengers (crying babies etc) and loud music or activities such as frantic typing. Such noises cannot be avoided. Furthermore the level of tolerance of the individuals is very different depending on age, temperamental characteristics, health status etc. Hence individualised flexible and intelligent active noise control is an appropriate strategy. The strategy has two main facets – tackling universally harmful vibrations and noises such as low frequency vibrations and engine noise and local attenuation of noise and vibrations through smart technologies. The rationale for this strategy is given below.

Vibrations affect the overall condition such as fatigue that is one of the major causes of stress. Vibrations again depend on the characteristics of different body parts. Appropriate smart textile materials used as upholstery, wall covers and carpets could be used to tackle this problem. The importance of this programme is beyond the integrated system so it is essential that the developed technology is capable of working as a stand alone system. This was achieved through the proposed active/passive dampening and noise reduction approach.

An extensive investigation was carried out on the possibilities of reducing in-cabin noise and vibrations by means of both passive and active solutions. In particular, the different sources (engines, airframes, other passengers, etc.), as well as their frequency and amplitude behaviour, were analysed and it has been logically concluded that passive components should reduce high frequency (> 500 Hz) annoyances and active devices should further improve both acoustical and vibrational fields. The study of the human behaviour under the effect of acceleration and noise was also considered. Initially, information about noise levels during flight were taken from the ISO standard 5129 (2001): Measurement of Sound Pressure Levels in the interior of aircraft during flight-. During the operational usage of the SEAT devices, sensors are used to detect noise levels and all capability to decrease internal noise depends upon their ability to obtain accurate information. The ability to transfer data quickly, accurately and to control and store all of the parameters needed is also an important requirement of the transmission systems and of the SEAT devices.

A precise knowledge of the human hearing is also required. Since the treble sounds are the most stressful sound for the human ear, the reduction in the range from 100 Hz to 7 KHz of the internal noise will give a significant improvement in the internal comfort. Another ISO Standard was used to model the behaviour of the human ear: ISO 226: 1987 -Normal equal loudness level contours: Fletcher-Munson curve-, and its successive modifications. Treble sounds have high frequency values, hence low wavelengths, whereas bass sounds have high wavelengths and low frequencies. A treble sound is created by rapid variations of few air molecules and the energy contained in it is quite low compared to that contained in a bass sound, generated by a low motion of a great quantity of air molecules. Thus, passive control, which consists on reducing the noise level by using foam and sound absorbing material, is indicated to reduce treble sounds, whereas active control is for low frequency. In fact the quantity of foam required to eliminate the bass energy should be too heavy in an aircraft. Moreover, within this project, sound absorbent materials are only inserted in the passenger seats.

The second strategy developed was based on active noise control through a set of secondary sources. This strategy allows good noise reduction in the internal cabin with a small increase in the aeroplane weight through the use of loudspeakers. Finally, one can use piezoelectric devices as loudspeakers, although fatigue is the main limitation of such devices. To achieve a significant attenuation of sound the secondary source required to be located in certain position of the cabin. As a result, a control strategy was established based on complementary experimental and numerical studies. A noise test campaign was first performed in Thales mock-up in order to get a starting point for improvements and data for the validation of numerical codes:

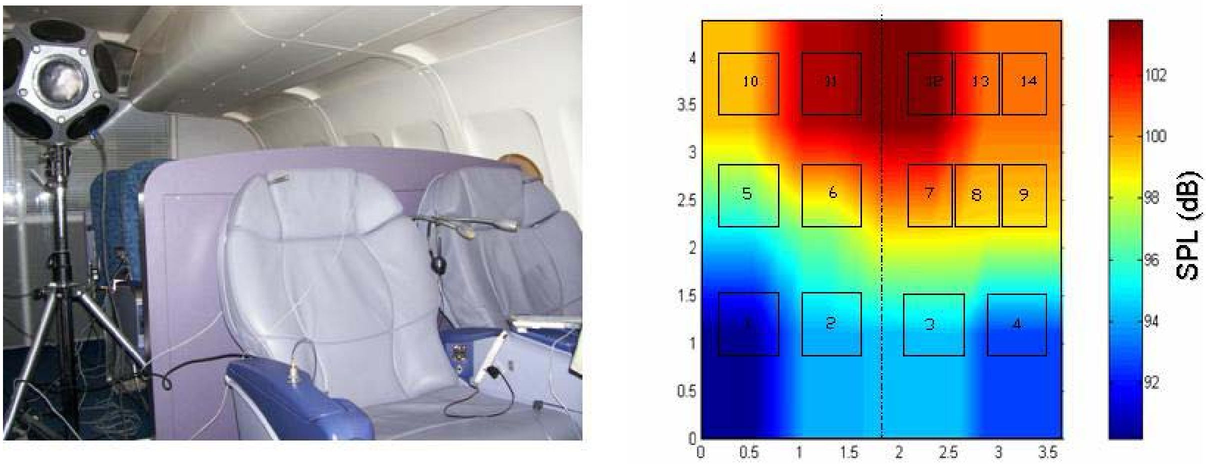



Figure 17: Experimental set up and measurments of noise inside the mock up cabin.

A vibration platform was further constructed for a similar study of structural annoyances:

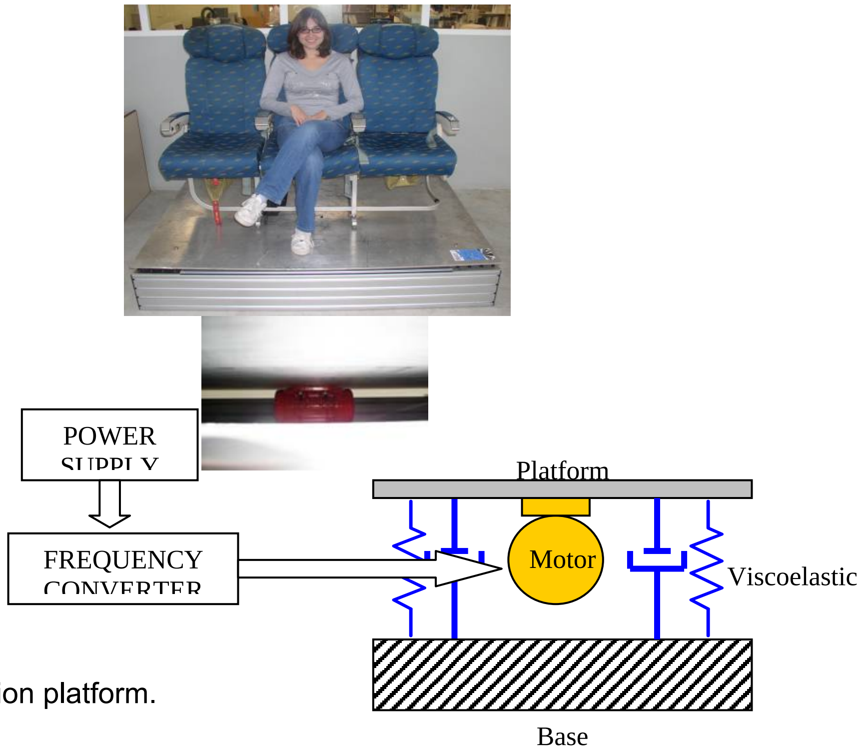



Figure 19: Vibration platform.

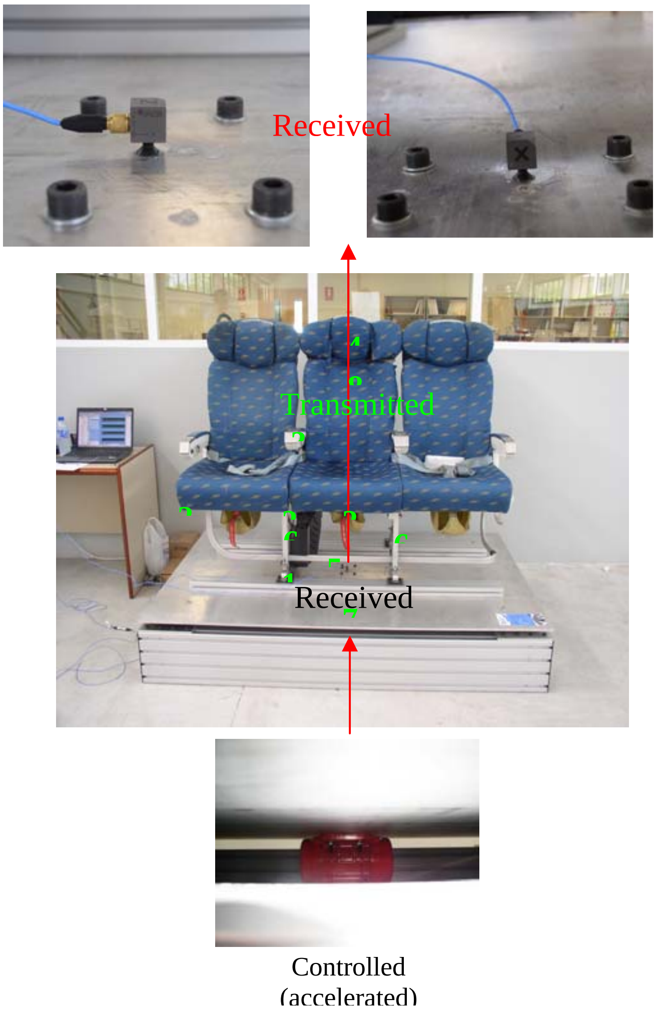



Figure 20: Vibration control system implemented on a row of three seats.

An in-house code was developed for more flexible and fast optimisation of passive and active noise reduction elements.

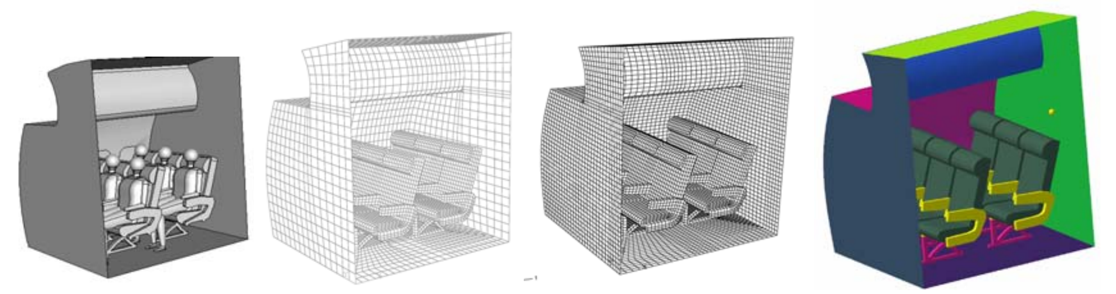


Figure 21

The sensitivity of the noise reduction with respect to both the seat textile and the seat geometry was evaluated: a portion of the aircraft cabin with two lines of three seats has been generated and meshed in order to perform the acoustic numerical simulations (see figure 21). Figure 23 shown the installation inside the mock up cabin and the computer model is presented in figure 24. The comparison between the computer model and experimental results are shown in figure 22.

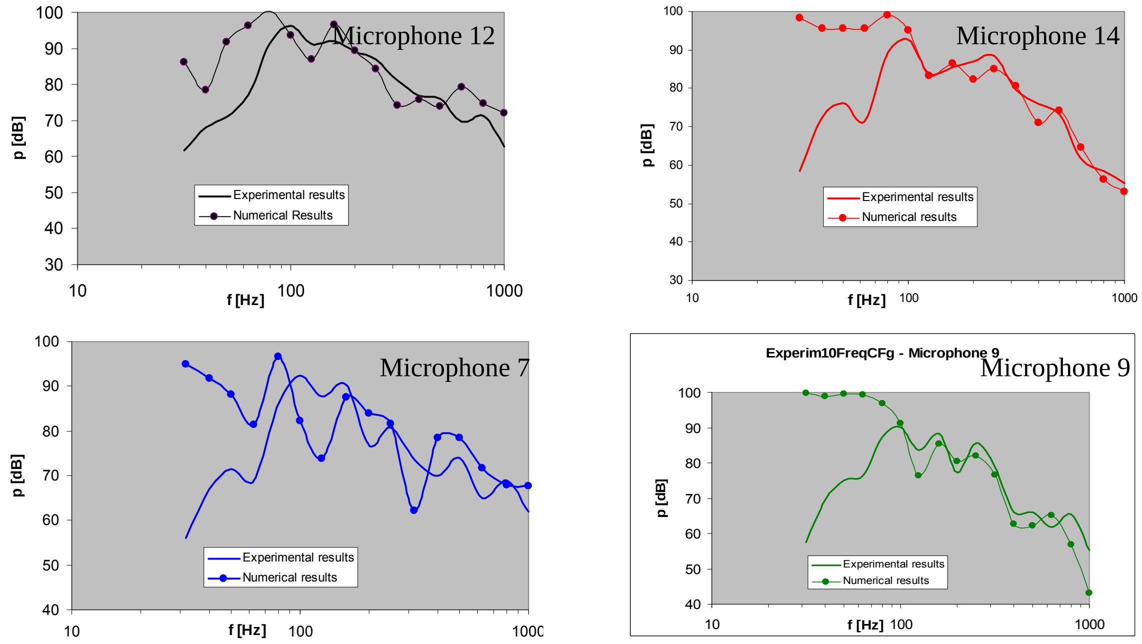



Figure 22

SEAT project introduced the idea of the bubble concept, which consists in creating around the passenger head a noise reduced area by utilizing two lateral insertions in the headrests of the seat. The bubble concept can be seen in figure 25. Further developments were introduced, such as a new design of the cushions for the headrests. Rather than using a block shaped cushion, a plate shaped cushion is used. The idea is to let air flow between each of the two headrests and hence increased the surface area (wetted area) of the cushions. Since the distances between the cushions are small, the energy of the waves travelling in between the cushions is effectively reduced when the waves are constantly reflected (high frequency range) in the wetted area. Ideally this reduces the noise pressure level by absorbing the acoustic wave energies. Another idea was to introduce different angles between the cushions and the headrests. Changing the angles of the cushions affects the phase of the sound waves, hence reducing the presence of standing waves at the ear level, and helps reducing the noise at the same level. In the new design, there is a large area of quiet zone in between the bubbles, and also in the areas of the passenger headrests close to the bubbles. The most significant quiet zone for the new design is at the windows seat at the back row. There is another advantage for this new model: it is closer to the real situation of the cabin seats. The back of the seats nowadays can move freely and individually. This new design allows the passenger move their seats with the bubbles and without affecting the passengers in the next seats.

Considering the comfort, at the middle of the seats, a negative degree seems to have a lower noise level than the positive degree cases when comparing with the same magnitude of angle. Therefore negative degrees are more efficient than positive degree designs. Looking at the improvements as percentage differences, the highest difference in all cases would be a super quiet cabin, with the cushions. This is no doubt because there are improvements done to nearly all parts inside the cabin. This raises a question of whether all these improvements are useful or not? In the super quiet cabin, improvements are also done for the floor. However, it is clearly shown that its effect is not significant enough. Moreover, the noise distribution is not even inside the super quiet cabin. It is unfair to the passengers sitting in the aisle seats where the noise level may be higher than the original cabin. Also, for all improvements done most of the materials inside the cabin would need to be changed. This may involve a huge amount of money if a fleet of airliners does not own only one aircraft. It doesn’t seem worthy to invest too much money for a partially improved cabin. Combining the results from all tasks, the simplest solution is the new bubble concept. By adding a gap in between the cushions there is a 4.4% improvement. The disadvantage of the solution is that it only improves the noise reduction at ear level. In order to cover this disadvantage, improvements for the absorbing coefficients of the walls are needed.


Figure 23

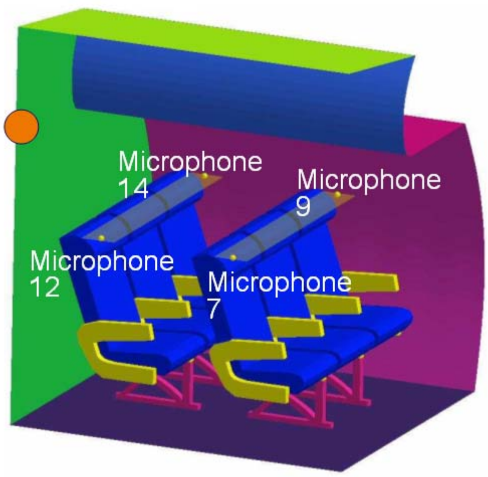



Figure 24: Cabin with microphone locations.

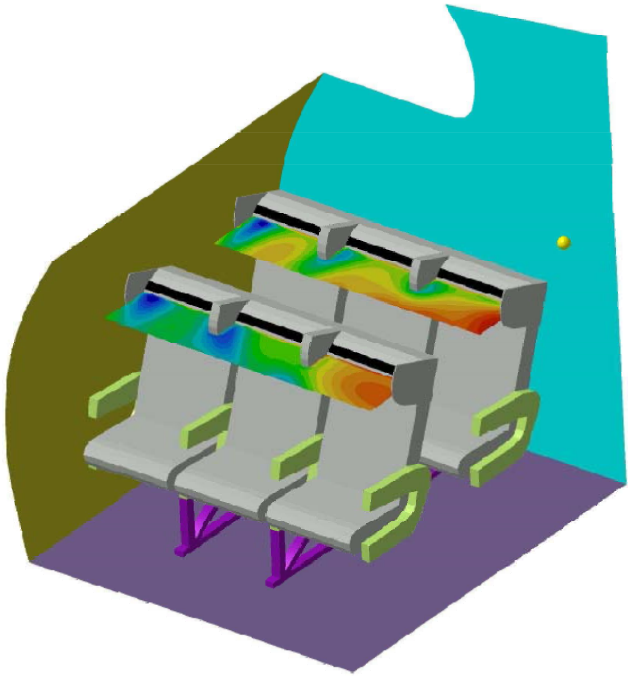


Figure 25. Cabin with seats including the bubble concept.

Comparing the results obtained in the old design and the new design (both are at 0 degree), there are significant noise reductions in most microphones. However the microphones are at the edge of the seats and therefore attention should be paid for the two extra points which are in the middle of the seats: mid front and mid back. The noise reductions in the middle part of the seats are significant. If looking at the back row of seats where microphones 12, 14 and mid back are, the improvements are much higher than the front row. The reason is because the bubbles are perpendicular to the noise source and the new design can effectively increase the energy dissipation of the waves directly travelling to the passengers. It should also be noticed that with a negative 10 degree change of bubble angle, the improvements are even greater. In average, there is a 4.4% improvement in noise reduction if the new design (addition of gap in between bubbles) is used. This shows that a simple change in the design without any change of material can already achieve half or even better than some of the results of the previous tasks.

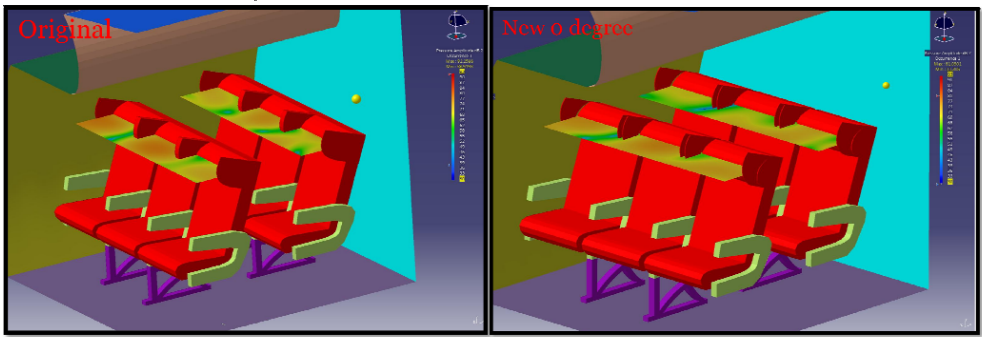



Figure 26: Noise distributions of the old and new design, both at 0 degree.

Figure 26 shows the noise distributions of the two designs. In the new design, there is a large area of quiet zone in between the bubbles, and also in the areas of the passenger headrests close to the bubbles. The most significant quiet zone for the new design is at the windows seat at the back row. There is another advantage for this new model: it is closer to the real situation of the cabin seats. The back of the seats nowadays can move freely and individually. This new design allows the passenger move their seats with the bubbles and without affecting the passengers in the next seats.

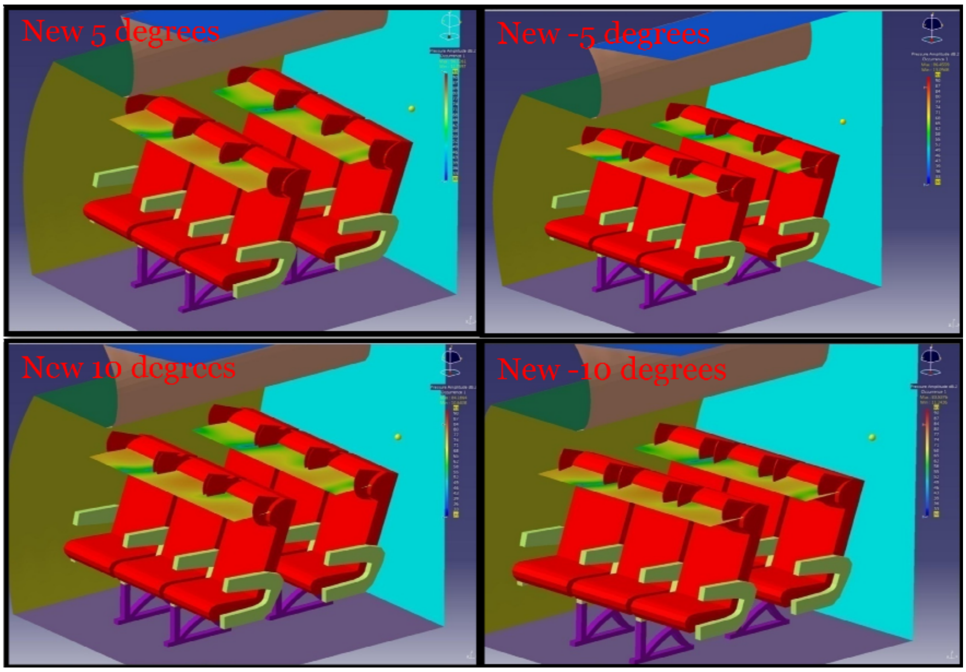



Figure 27: Noise distributions of the new design.

Figure 27 shows the four new designs with different angles of the bubbles are facing outward of the seats while a negative on the angle is in negative degree, the relative spaces in between the bubbles are larger when they are further away from the headrests. From the figure 4, the quiet zones for the negative degree cases are larger. Considering the comfort, at the middle of the seats a negative degree seems to have a lower noise level than the positive degree cases when comparing with the same magnitude of angle. Therefore negative degrees are more efficient than positive degree designs.

Looking at the improvements as percentage differences, the highest difference in all cases would be a super quiet cabin, with the cushions. This is no doubt because there are improvements done to nearly all parts inside the cabin. This raises a question of whether all these improvements are useful or not? In the super quiet cabin, improvements are also done for the floor. However, it is clearly shown that its effect is not significant enough. Moreover, the noise distribution is not even inside the super quiet cabin. It is unfair to the passengers sitting in the aisle seats where the noise level may be higher than the original cabin. Also, for all improvements done most of the materials inside the cabin would need to be changed. This may involve a huge amount of money if a fleet of airliners does not own only one aircraft. It doesn't seem worthy to invest too much money for a partially improved cabin. Combining the results from all tasks, the simplest solution is the new bubble concept. By adding a gap in between the cushions there is a 4.4% improvement. The disadvantage of the solution is that it only improves the noise reduction at ear level. In order to cover this disadvantage, improvements for the absorbing coefficients of the walls are needed. The advantage of the wall improvements is that it can produce an evenly distributed noise level inside the cabin which can cover the parts that are outside the ear level. By combining the two ideas, an effective solution for noise reduction in aircraft cabin could be produced.

Moreover, a formulation to evaluate the optimum location of the noise attenuated area and the optimum orientation of the secondary source has been also developed and implemented. The optimization procedure is based on an iterative approach; hence the final location is evaluated after a series of intermediate positions. The results of an analysis are here presented. The cabin has been disturbed by a monopole located in c) that stands as the airplane engine. Location a) is the starting location; b) is a series of intermediate positions; e) is the optimum final location and d) is a location that approximates quite well the optimization location. The frequency of the disturbing noise is 70Hz.

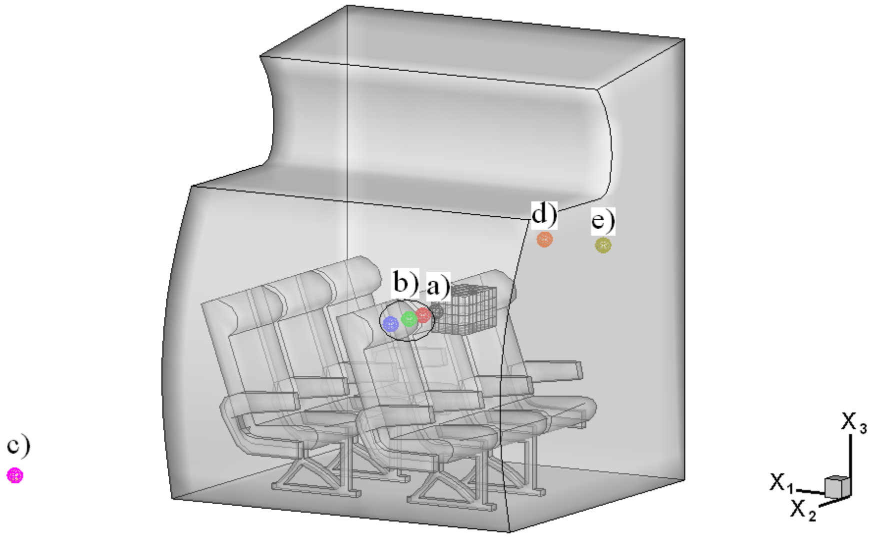



Figure 28. Secondary source location at various iterations.

***Interactive and integrated entertainment***

The enclosed environment of the aircraft causes both physiological and psychological discomfort and even stress. Many airlines have realised the potential of the on-board entertainment in improvement of customers' satisfaction level and opted for provision of different games moving up to on board quiz show. However, again this approach is based on pre-set concept of what customer likes and requires as a homogeneous passenger group that has similar tastes and desires. However it is interesting to note that research has shown that first class passengers are less likely to opt for this type of entertainment than that of the economy ones. This leads to understanding that the entertainment is acting as a sweetener for relatively poor services and that features such as office facilities are likely to come higher in customers' priorities than entertainment. However, this is not the entire story as the quality of the entertainment and the appeal to personal taste changes customers' attitude. Furthermore, this is possibly a wrong question to ask. The question should not be entertainment or office but entertainment and office and home comfort. On this premise one will find that contextually selected entertainment could bring better working results and reduced health risk but should allow for appropriate customer interaction.

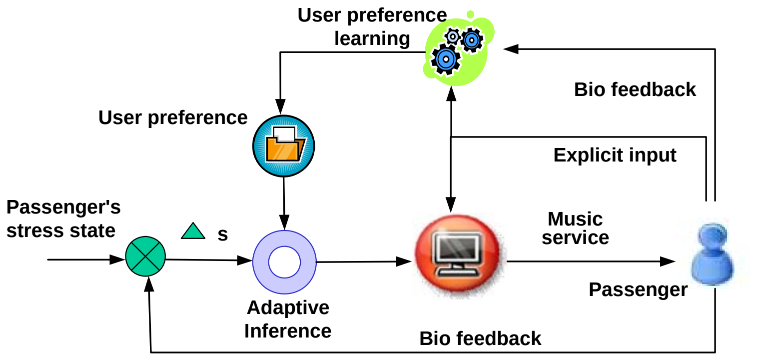
It is therefore essential that the entertainment and office environment are integrated without causing discomfort to other passengers and reflecting the needs and desires of the user. The entertainment might be divided into three categories. The first is *passive entertainment,* where passenger does not participate and simply enjoys a chosen form of entertainment that may be simply a noise shield or relaxation tool. The next level is *active entertainment* where an appropriate means for limited exercise that tackles immobilisation, bad posture etc is provided. Through innovatively devised controls linked with appropriate devices it could deliver good health benefits. The work on the active entertainment will be closely linked with WP1 as it needs to intelligently address the needs of the passenger and more importantly with WP5 to ensure that is compatible with the central system and with the other workpackages.

The third and highest level is the *intelligent entertainment* where subliminal system generated responses aim to improve passenger's mood, reduce the stress etc through use of subliminal stimuli such as sounds scents and images.

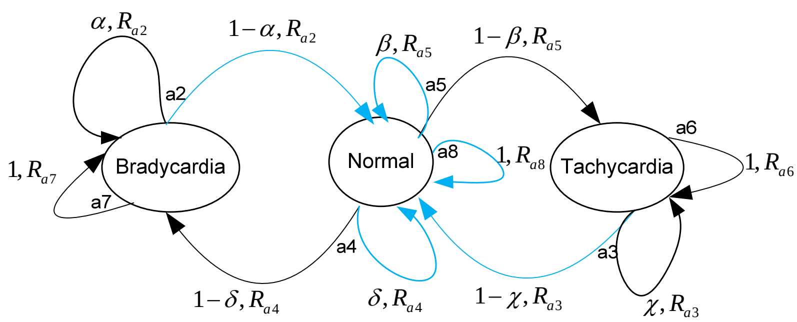
**A novel system that allows interactive entertainment at different levels – individual, group and central.**

TUE designed a new adaptive music framework for stress free air travels. It integrates the concepts of context adaptive systems, user profiling, and methods of using music to reduce stress into a linear feedback control system. In case of the linear feedback system, a control loop, including the non-intrusive sensor for the passenger's bio signal acquiring and modelling, adaptive control unit for music adaptation strategies, etc. components, is arranged in such a fashion as to try to regulate the passenger's stress state to the target stress state with personalized music playlist recommendation. In the figure 29 (a), the framework starts by setting the passenger's target stress state. Then, the system begins observing the passenger's stress state which is based on the bio signal that it wishes to control. After that, depending on the difference between the target and the current stress states, the adaptive inference component in the framework must determine (1) whether the passenger is in the target stress state or not; and (2) if the passenger is not in the target stress state, then an optimized music playlist is recommended based on user music preference, context of use and available music etc. information to transfer the passenger from the current stress state to the target stress state with the minimum time cost. The passenger himself/herself is an adaptive system; his/her perception creates an internal representation of the music. This perception affects the passenger's stress state. During this process, the passenger's stress state may also be influenced by the set of variables which in the control system called disturbances. The change in the passenger's stress state is again perceived by the system, and this again triggers the adaptation process we have described, thus closing the control loop. In figure 30 (a), if the framework recommends music that the passenger does not like, he/she may reject the recommended music and select desired music himself/herself or just shut down the system. By mining on interactions between the passenger and the system, the framework can automatically learn and adapt to the passenger's latest music preference.

In this project, the passenger's stress states are modelled with tachycardia, normal and bradycardia three states which are based on the heart rate. For a child (age 6-15), his/her normal heart rate should be 70-100 (normal state). If his/her heart rate is higher than 100, he/she is in the tachycardia state; if his/her heart rate is lower than 70, he/she is in the bradycardia state. For an adult (age 18 and over), his/her normal heart rate should be at 60-100 (normal state). If his/her heart rate is higher than 100, he/she is in the tachycardia state; if his/her heart rate is lower than 60, he/she is in the bradycardia state. The target of the adaptive frame is to keep the passenger's heart rate within the normal state (figure 29 (b)).




(a) Adaptive music framework for stress free air travels




(b) Heart rate as an indicator of stress

Figure 29: Adaptive music framework

Based on the adaptive framework, TUE designed the software architecture support, and implemented the Browser/Server web based interactive music system. Figure 30 shows the main components that make up the software architecture. The architecture is divided into five abstraction levels from the functionality point of view. The lowest level is the resource level which contains music, heart rate sensor and user static profile information such as demographic information. The second layer is the resource manager layer which includes music manager, context of use manager and user profile manager. The music manager is responsible for the in-flight music registration, categorization, un-registration, etc service management functions. The context of use manager collects and models signals from the heart rate sensor and updates the heart rate information in database. The user profile manager collects, and updates the user's static information such as demographic information. The third layer is the database layer which constitutes by a database. It acts not only as a data repository, but also enables the layers and the components in the layers loosely coupled. This increases the flexibility of the architecture. For example, replacing or updating components in the resource manager layer does not affect the architecture performance unless data structures in the database are changed. The fourth layer is the adaptive control unit layer which includes user feedback log, adaptive inference. It is used to mediate between the user profile, context of use and available music contents to recommend the passenger personalized music playlists to transfer the passenger from the stress state to the target stress state. The user feedback log component is responsible for logging the user's feedback to the recommended music. The adaptive inference is the core component of the architecture. It is used to mediate between the available music, context of use and the user profile etc. information with Markov decision processes to: (1) recommend the minimum cost (e.g. time cost) personalized music playlist to the passenger; (2) Learn the passenger's latest music preference by learning on the user's past interactions with the recommended or self selected music. The fifth layer is the interface layer. The passenger interacts with the adaptive in-flight music system interface to get personalized music services. The adaptive music system software is implemented with Browser/Server architecture. The Server side includes a self developed http request/reply server, music streaming server, music manager, user profile manager, adaptive control unit.

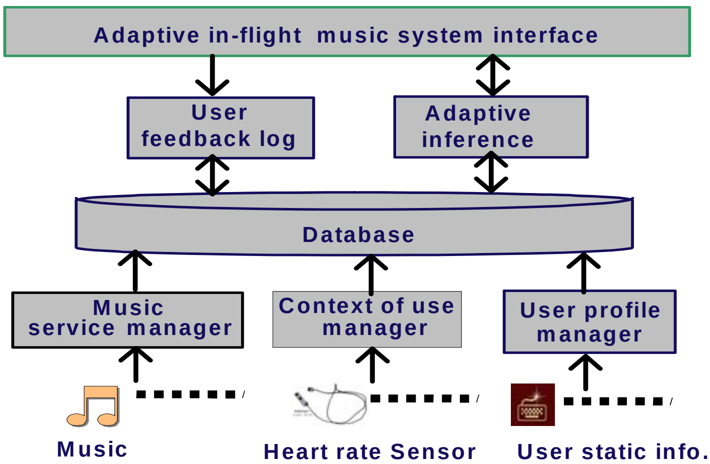



Figure 30 Software architecture support for the adaptive framework

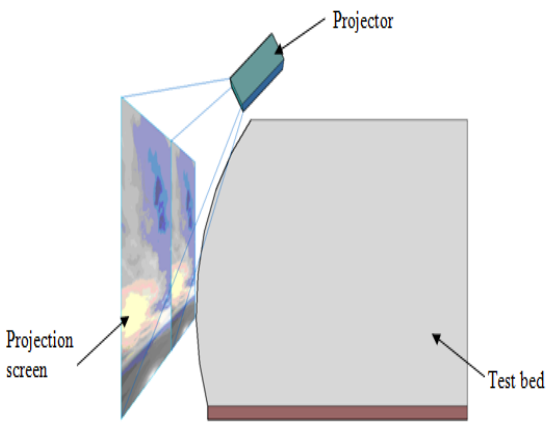
TUE designed and constructed a test bed which aims to simulate long haul flights to validate design concepts. The test bed is composed by an aircraft cabin which resides on a moving platform (refers to figure 31), a control section and a projection section. The aircraft cabin is composed mainly by an economy class section, a galley section for the food, drink storage, and a lavatory section (refers to figure 3 and figure 4). For each economic class seat, there is an in-seat touch screen for entertainment and an in-seat non intrusive heart rate sensor. The projection section include a beamer hangs above the aircraft cabin and a projection wall next to the aircraft cabin. The control room is equipped with the state of art of computers to support the beamer in the projection section, in-seat computers in the aircraft cabin, and a computer to flate/deflate air bags to move the aircraft cabin to simulate the take off, landing, turbulence, flying situations, etc.

(a) Main entrance

(b) Galley

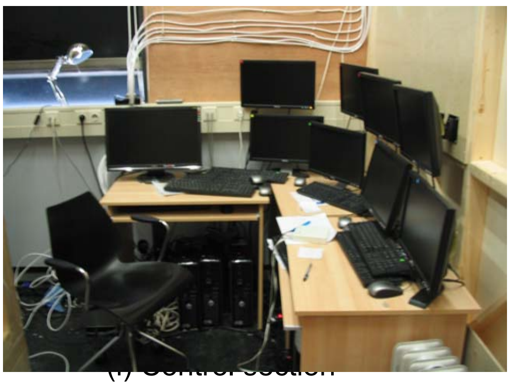
(c) Lavatory

(d) Economic class




(g) Compressed air

(h) Airbag



(f) Control section

Figure 31 Test bed

TUE did the user experiments to validate the adaptive music framework for stress free air travels. Twelve subjects were invited to participate in user experiments. Six were allocated to the controlled group and others were allocated to the treatment group. The ages of the control group range from 21 to 33. The ages of the treatment group range from 23-32. The professions in the control group include one reporter, two workers and three engineers. The professions in the treatment group include one student, two workers and three engineers. KLM KL0895 flight from Amsterdam Schipol international airport (6:20PM) to Shanghai Pudong international airport (10:45 AM <Shanghai time>, 4:55AM <Amsterdam time>) is simulated in TUE test bed on 31st (Friday), July 2009 (the controlled group user experiment) and 7th (Friday), August 2009 (the treatment group user experiment). Figure 32 presents the exact time of the flight flying stages.

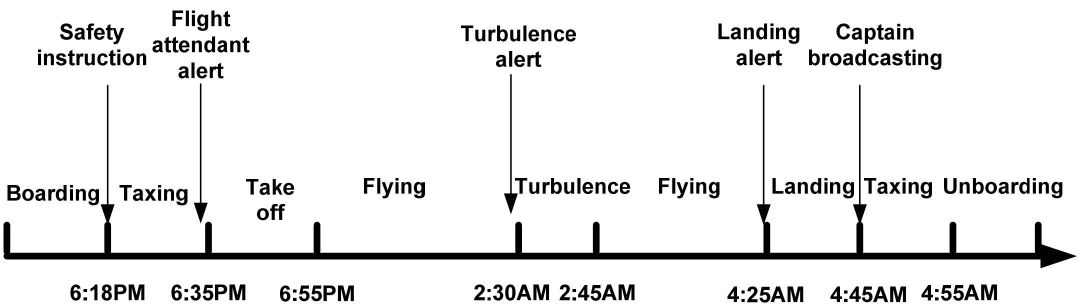


Figure 32 Flying stages

Figure 33 User experiment

TUE developed a new time-aware in-flight entertainment (image) system for stress (jet lag) free air travels. Based on the passenger’s bio clock indicated by melatonin, the system adapts the color of the in-flight entertainment system interface, movies and lighting (refer to figure 10) to change his/her circadian rhythm.


Figure 34 Adaptive entertainment interface, movies and lighting

**Implementation of physical activities in terms of desired locomotion patterns as part of the entertainment.**

TUE developed a new in-flight game chair to promote long haul flight passenger's physical comfort. A matrix of Force Sensing Resistor (FSR) sensors is installed in the chair as the game playing inputs (gestures). The sensor's outputs are used as inputs of a neural network to recognize the user's three types of gestures. A balancing game which is easy to understand and preferably excluding unwanted learning behavior is developed. If the passenger feels physically uncomfortable, he/she can play the balancing game by uplifting his/her legs

During the execution of the WP4, two items had to be achieved by AITEX and ANTECUIR: "*Investigation into ubiquitous peripheral computing/entertainment devices*" and "*Feasibility of use of smart textile interfaces*". Both were closely interrelationed because the results of the investigations done in each point showed the feasibility of the smart textile use as peripheral entertainment device.

Therefore, a smart carpet which interacts with the passenger in order to command some parts of the entertainment system was decided to be done. The general idea was utilizing the carpet as a quantifier pressure sensor for two complementary applications. The first one was to be an interface for playing with some games which should be developed for the entertainment system. The second one was to reduce the chance of suffer the tourist class syndrome, using the pressure powered by the passenger legs, while playing, for activating the blood circulation and avoid the risk of thrombosis, which can appear after a long time of immobilization.

Therefore the work was divided regarding the experience of both partners. ANTECUIR performed the task of create the smart carpet structure, developing a electrical capacitor inside the carpet structure with two independent zones, one for each foot, which create a pressure sensor.

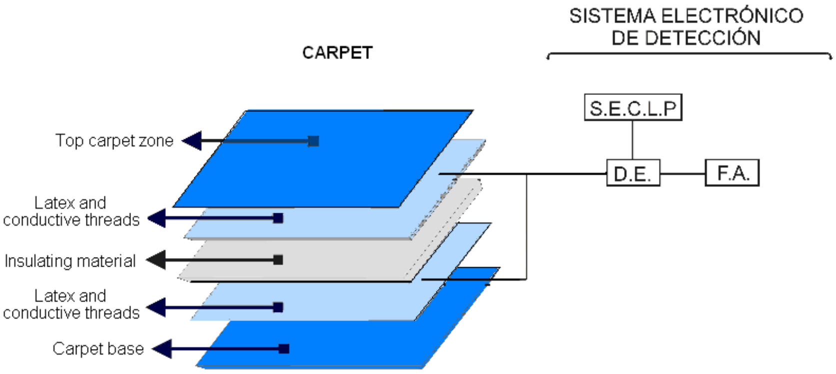



Figure 35: Carpet sensor structure

Several trials with many different materials were done for developing the two conductive surfaces of the capacitor. Finally, carbon powder was utilized for blending with the latex that is normally used in the carpet industrial process. Many percentages of carbon powder where mixed with the latex and finally the right dispersion and conductivity of the mixture were achieved. The final carpet structure is completely industrial and economical feasible. AITEX carried out the work of development of the electronics (microcontroller) which charged the capacitor and detected the electrical capacitance variation (Voltage) signal. The electronics also transformed the analogical signal produced in a digital one, which was able to be understood by the system software and the game programmed. AITEX also developed this demonstrator game for its installation in the entertainment configuration.

A microcontroller (μC) is a computer-on-a-chip, containing a processor, memory, and input/output functions. It is a microprocessor emphasizing high integration, in contrast to a general-purpose microprocessor (the kind used in a PC). In addition to the usual arithmetic and logic elements of a general purpose microprocessor, the microcontroller integrates additional elements such as readwrite memory for data storage, read-only memory for program storage, EEPROM for permanent data storage, peripheral devices, and input/output interfaces. Power consumption while sleeping may be just nanowatts, making them ideal for low power and long lasting battery applications.

The final result can be seen in the next picture (figure 34) which shows the carpet and the game developed.


Figure 36: Picture 1: SEAT playing carpet

**Integration of office characteristics in the entertainment environment to allow effortless switch to different modes of activities.**

TUE designed and implemented in-seat infrastructures and an in-flight entertainment system to integrate office characteristics seamlessly in the entertainment environment to allow effortless switch between work mode and entertainment mode. The in-seat infrastructures include an in-seat USB port and a flexible keyboard. If the passenger wants to work on an office file in a USB stick, he/she can insert the USB stick in the in-seat USB port, and then the passenger can open the word file by a popup menu. After that, the passenger takes the in-seat flexible keyboard and works on the word file. The mode then switches from entertainment to work. After the passenger finishes the work and closes the word file. The passenger sees in-flight entertainment interface again.

DHS contributed - the **IFE** (In Flight Entertainment) system. DHS generated an adaptive GUI model based upon an "Adaptive User Matrix". It was not intended as a definitive GUI, more as a model to be integrated into the TU/e outputs. It provided a focus on the sort of front end adaptive GUI layers that would identify the interface bottlenecks and make the system most suitable for the greatest number of users.

### *Development of integrated adaptable system SEAT Demonstrator*

This work package was central to the programme as it represents the core of the proposed system – creation of flexible and responsive customer centred cabin environment. The concept is unique in its focused on smart user responsive technologies that provide a different level of comfort provision through. The SEAT system is not based on offering unlimited number of options but a self-adapting system that integrates such options in a unique non-intrusive way.

In Thales premises in Toulouse, we integrated the different equipment from SEAT projects in our IFE Mock-Up laboratory (see figure 37). The SEAT Demonstrator was divided in 3 areas which were very close each other.

Figure 37: Mock up cabin

## Area 1 : Cabin Environment : SEAT Comfort Integrated Platform

Figure 38: Thales Mock-Up : Integrated SEAT in Cabin Environment

For the comfort platform a row of three seats was set up in the mock up cabin as shown in figure 36. SEAT A (window seat) is used for the physiological monitoring and implements the passive bubble concept. SEAT B is used for the In-Flight Entertainment System, the active carpet, and the lateral loudspeaker noise reduction. SEAT C (aisle) is used for the climatic and postural controls, the face temperature sensor and the active flat loudspeaker noise reduction.

A computer was used to control the physiological monitoring. The same PC, an intermediate application that receives the ECG data, extracts the heart beat rate and stores the results in the SEAT database were installed. Another computer was used for the management of the climatic and postural controls, as well the comfort model

Two further computers were used for the In-Flight Entertainment; one server and one client. A computer to show the simulations/material of the. A panel with the IR sensor in front of the seat C, and three screens one for each seat and an Ethernet switch to interconnect all the computer in a single net.
Each screen must support one user interface according with the seat associated. Physiological UI - Screen in front of seat A shall respond according with the physiological monitoring. Entertainment UI - Screen in front of seat B shall support the SEAT Flight Entertainment System. Comfort UI - Screen in front seat C shall respond according with the climatic and postural controls. This is the actual scenario for the mock up and this is how the demonstrations were carried out. The following illustrations show the screen integration and the overhead screen used for demonstration:

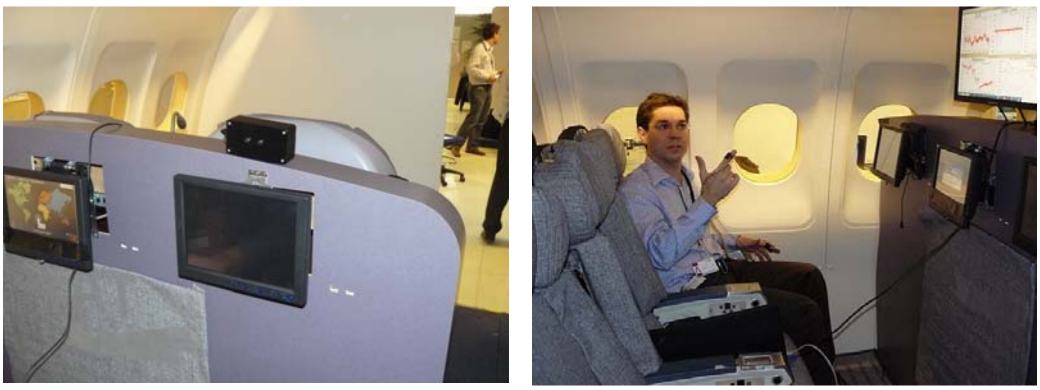


Figure 39

The following illustrations show the integration of the active carpet in the Cabin environment:

Figure 40

**Pressure sensors**

The pressure mat was place in the seat cushion, over foam of specific characteristics. A thin layer of soft fabric covered it in order to make the sensor mat not detectable when passenger sitting.

Figure 41: Positioning of the pressure mat and sensors label

**Active Noise control in the Cabin Environment**

Both flat and cone shape speakers were integrated in the Seats


Figure 42: Integration of speakers into the seats.

**Aera 2 : Smart Seat Ventilation System**

Thanks to the work and the experimentation done, the CFD model of the proposed ventilation system in the cabin sector proved : compactness of the local microclimate pocket in the passenger's area; increased level of RH in breathing area of passenger by 10%; low level of RH close to the cabin walls (reduced risk of water condensation) ; sufficient shielding effect of the passenger from the contaminants in the cabin air; low water consumption, 0.08 kg/hour/passenger; limited temperature control **;** Illustrations of the experimental verification :

Figure 43: Humidity control plateform

**Area 3 : Vibration Platform**

In this area, we installed the vibration platform to illustrate the vibration dampening system. Characteristics of Vibration platform, passive & active dampening: Vibration platform 1800x1200mm; Frequency range: Motor with eccentric mass:1 to 50 Hz; Electromagnetic vibration transducer: Over 100Hz; MagnetoRheoLogical dampening; Weight : 250 kg (seats included)

Figure 44: Vibration control platform

In Thales Mock-Up, the demonstration was done during the final review meeting and the Advisory group workshop.

***Publications***

**Partner: ICT**

**Journal Publications:**
A.Brancati, M.H.Aliabadi, I.Benedetti, Hierarchical Adaptive Cross Approximation GMRES Technique for Solution of Acoustic Problems Using the Boundary Element Method. *CMES: Computer Modeling in Engineering & Sciences* 43 (2009) 149-172.

Mallardo V., M.H. Aliabadi. *"The Dual Reciprocity Boundary Element Method (DRBEM) in nonlinear acoustic wave propagation"*, CESES International Journal of Computer and Experimental Simulations in Engineering and Science, 2, pp. 7-18, 2008.

Mallardo V., M.H. Aliabadi. *"A novel DRBEM application for nonlinear wave propagation"*, Commun. Numer. Meth. Engng, 2009 (DOI: 10.1002/cnm.1301).

**Conference presentations:**

Mallardo V., Aliabadi M.H., "A BEM approach in nonlinear acoustics", International Conference on Boundary Element Techniques IX 9-11th July, Sevilla, Spain. In:Advances in Boundary Element Techniques IX, Edited by R. Abascal and M.H. Aliabadi, 2008, Published by EC ltd, UK, pp. 439-444 (ISBN 978-0-9547783-5-4).
Mallardo V., Aliabadi M.H., "A fast multipole boundary element method for two-dimensional acoustic wave problems", International Conference on Boundary Element Techniques X 22-24th July, Athens, Greece. In:Advances in Boundary Element Techniques X, Edited by E.J. Sapountzakis and M.H. Aliabadi, 2009, Published by EC ltd, UK, pp. 203-208 (ISBN 978-0-9547783-6-1).
Mallardo V., M.H. Aliabadi "Noise control by BEM in large scale engineering problems", XIX Congresso Nazionale dell'Associazione Italiana di Meccanica Teorica ed Applicata AIMETA, Ancona, Italia, 14-17 settembre 2009 (extended paper on CD-ROM) (abstract su ISBN 978-88-96378-08-3, p. 362-362, aras edizioni).
Brancati, M. H. Aliabadi, I. Benedetti "Rapid acoustic boundary element method for solution of 3D problems using hierarchical adaptive cross approximation GMRES approach", Proceedings of the X International Conference on Boundary Element Techniques, (BeTeq 2009), 2009, Athens, Greece.
Benedetti I., Aliabadi M.H. "Fast Solution of 3D Elastodynamic Boundary Element Problems by Hierarchical Matrices", Proceedings of the X International Conference on Boundary Element Techniques, (BeTeq 2009), 2009, Athens, Greece.

ACU
Acustel have presented paper at industrial meetings, most notably at a national exhibition in Spain and the international Expo in Paris.

AIT
57th International Astronautical Congress (2-6 October 2006, Museo Príncipe Felipe, Ciutat de les Arts i les Ciències, Valencia, Spain). AITEX manned a stand from IMPIVA (Regional Goverment) with posters including on the SEAT project. See http://www.iac2006.com.

DIFUTEC Workshop: "Opportunities of technologies of Spanish Aeronautics-Aerospacial sector for Valencian companies", Salón de Grados del Campus de Alcoy de la UPV. 4-5th October 2006. AITEX manager carried out a speech about AITEX and SEAT project.

CTU

Zítek P, Vyhlídal T, Simeunović G, Nováková L, Čížek J. CFD Model Aided Design of Personalized Air Supply for Aircraft Cabin Seat. In Proceedings of the 6th Vienna Conference on Mathematical Modelling [CD-ROM]. Vienna: ARGESIM, 2009, p. 2236-2245. ISBN 978-3-901608-35-3.
Zítek P, Simeunovič G, Vyhlídal T. Personalized Air Distribution System for a Seated Passenger in Aircraft Cabin. In Proceedings of the 11th International ROOMVENT Conference [CD-ROM]. Seoul: Seoul National University, 2009, p. 987-994. ISBN 978-89-89071-02-0.

**Conference Presentations**

Zítek P, Vyhlídal T, Simeunović G. Personalised Air Supply of the Airplane Cabin Seats. Presented as an invited lecture at Annual Conference of the Czech and Slovak university departments of Automatic Control, Brno, September 2008.
Vyhlídal T, Zítek P, Simeunović G. The Personalized Air Distribution System for a Seated Passenger in Aircraft Cabin, Poster presentation at the Technical Conference on Automatization, Control and Processes, ARAP 2008, CTU in Prague, 4-5. 11. 2008.

**ETHZ**

Conference Presentations
Monitoring passenger's breathing - a feasibility study Basem Dokhan, Cornelia Setz, Bert Arnrich and Gerhard Tröster in: Swiss Society of Biomedical Engineering Annual Meeting, Neuchâtel, Switzerland, 2007
Effect of movements on the electrodermal response after a startle event Johannes Schumm, Marc Bächlin, Cornelia Setz, Bert Arnrich, Daniel Roggen and Gerhard Tröster, in: Proceedings of 2nd International Conference on Pervasive Computing Technologies for Healthcare (Pervasive Health), 2008
Automatic Signal Appraisal for Unobtrusive ECG Measurements Johannes Schumm, Sebastian Axmann, Bert Arnrich and Gerhard Tröster in: Proceedings of the Biosignal Interpretation Conference, 2009
Quantifying Gait Similarity: User Authentication and Real-World Challenge Marc Bächlin, Johannes Schumm, Daniel Roggen and Gerhard Tröster in: Advances in Biometrics, Third International Conference, ICB 2009, Alghero, Italy, June 2009. Proceedings, Springer Berlin / Heidelberg, 2009
Using Ensemble Classifier Systems for Handling Missing Data in Emotion Recognition from Physiology: One Step Towards a Practical System Cornelia Setz, Johannes Schumm, Claudia Lorenz, Bert Arnrich and Gerhard Tröster in: Proceedings of the 2009 3rd International Conference on Affective Computing and Intelligent Interaction, ACII, 2009
Combining Worthless Sensor Data Cornelia Setz, Johannes Schumm, Claudia Lorenz, Bert Arnrich and Gerhard Tröster in: Presented at the Measuring Mobile Emotions Workshop at MobileHCI, 2009

Journal Papers
Marc Bächlin, Cornelia Setz, Bert Arnrich, Daniel Roggen and Gerhard Tröster (2008) Effect of movements on the electrodermal response after a startle event Johannes Schumm, , in: Methods of Information in Medicine, 47:3(186-191)

**QM**

**Conference Presentations (research)**
Dabnichki P (2009) Pervasive computing approach to thermal regulation, 7th Int Symposium on Computers in Sport, AIS, Canberra, Austrtalia
Dabnichki P (2009) Smart airplane environment, Proc. of MATHMOD09, Austria, Vienna

Dabnichki P (2008) Pervasive computing and mathematical models in sport: potential for performance improvement. Dagstuhl seminar "Computer science in sport - Mission and methods
Djumanov D and Dabnichki, P. (2008) DinamapBP - Automatic Data Acquisition System for Clinical Trials. 2nd International Conference on Pervasive Computing Technologies for Healthcare 2008. Tampere, Finland
Dabnichki, P. (2007) Intelligent technologies and sport performance. Proc. of the 6th Int. Symposium Computer Science in Sport, Calgary, Canada.

Conference Presentations (industrial)

Smart Seat for Aeroplanes – current trends and future developments, Presentation to aeronautical industry, London, 2007
Pervasive Technologises for Monitoring Neurological Patients, e-home and e-care event organised by the London Technology Network, London, 2008.
SEAT Project and the Potential for Smart Office Environment, e-home and e-care event organised by the London Technology Network, London, 2008.
Presentation to Dasault and EADS research on SEAT project features, Paris, 2008.
Smart Seat for Aeroplanes, London Technology Network sponsored presentation to industry, London, 2009
Intelligent System for Individualised Temperature Control in the Workplace, presentation to RIBA, 2009
A Portable System For Patient Monitoring And Recording, Monitoring and medical assistance, event organised by the London Technology Network, London, 2009
Monitoring and Analysis of Patient Condition and Response to Treatment, Monitoring and medical assistance, event organised by the London Technology Network, London, 2009
Smart Seat for Aeroplanes, Presentation to TU Vienna and University of Vienna, 2009
Behavioural Pattern Recognition of a Seated Person, Security and air travel event organised by the London Technology Network, London, 2009
Monitoring and Tracking Unusual Behavioural Patterns. Presentation to Security experts from industry and civil service, 2009.

**TUE**

**Book chapter:**

Liu H.,Salem B., Rauterberg M. (2009). "Towards Next-Generation In-Flight Entertainment Systems: A Survey of the State of the Art and Possible Extensions", Chapter 5 of Advances in Semantics Media Adaptation and Personalization (pp. 95-111), CRC Press, 2009.

**Conferences:**

Liu H.,Hu J., Rauterberg M. (2009). Software architecture support for biofeedback based in-flight music systems. In: Proceeding of 2nd IEEE International Conference on Computer Science and Information Technology (pp.580-584), 2009. IEEE Press ISBN: 978-1-4244-4519-6.
Liu H. ,Hu J., Rauterberg M. (2009). Bio-feedback Based In-flight Music System Design to Promote Heart Health. In: Proceedings of 2009 International Conference on Information and Network Technology (pp.446-450), 2009. IEEE Press.
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Tan, C.F. Chen, W. and Rauterberg, M. "Design of aircraft cabin testbed for stress free air travel experiment". 5th International Conference on Planning and Design, Tainan City, Taiwan, 25-29 May 2009.
Tan, C.F. Chen, W. and Rauterberg, M. "Interactive aircraft cabin testbed for stress-free air travel system experiment: an innovative concurrent design approach". International Conference on Advances in Mechanical Engineering ICAME 2009, Shah Alam, Malaysia, 24-25 June 2009.
Tan, C.F. Chen, W. and Rauterberg, M. "Creative thinking of design and redesign on SEAT aircraft cabin testbed: a case study". 14th International Conference on Thinking, Kuala Lumpur, Malaysia, 22-26 June 2009.

Tan, C.F., Chen, W. and Rauterberg, M. “Self-reported seat discomfort amongst economy class aircraft passenger in the Netherlands”. World Congress on Bioengineering 2009, The Hong Kong Polytechnic University, Hong Kong, China, pp. 211, 26-29 July 2009.
Tan, C.F., Chen, W., Kimman, F. and Rauterberg, M. “Sleeping posture analysis of economy class aircraft seat”. World Congress on Engineering 2009, London, U.K., pp. 532-535, 1-3 July 2009.
Liu H.,Hu J., Rauterberg M. (2008). AIRSF: A New Entertainment Adaptive Framework for Stress Free Air Travels . In: Masa Inakage & Adrian David Cheok (eds.): Proceedings of the International Conference on Advances in Computer Entertainment Technology (pp. 183-186). ACM Press.
Liu H., Salem B., Rauterberg M. (2008). Adaptive User Preference Modeling and Its Application to In-flight Entertainment . In: Proceedings of 3rd International Conference on Digital Interactive Media in Entertainment and Arts, ACM ISBN: 978-1-60558-248-1, pp. 289-294.
Westelaken van de R., Hu J., Liu H., Rauterberg M. (2008). Integrating gesture recognition in airplane seats. Lecture Notes in Computer Science, Vol. 5093, pp. 353–360.
Liu H., Rauterberg M. (2007). Context-aware in-flight entertainment system. In: MJ. Dainoff (Ed.) Proceedings of Posters at HCI International: Part X (LNCS CD-Rom [ISBN 978-3-540-73332-4], pp. 1249-1254), Springer.

## *Conclusions*

The basic objective of the proposed project was to contribute to the creation of an integrated cabin system – SEAT that addresses different aspects of travel comfort and on-board services. Through the use of smart technology SEAT developed a system to address passengers’ needs and requirements in a none-intrusive manner. The system is expected to improve customers’ satisfaction level by tackling factors that are of prime significance in customers’ perception of quality of air travel.

One of the **major innovations** of the SEAT project is the development of a novel integrated cabin environment that incorporates:

- physiological monitoring with health alert option that is not in existence in aircraft;
- “smart seat” that actively addresses potential health hazards and is an integral part of the on-board entertainment;
- “smart textiles” and other smart technologies in vibration dampening and noise reduction
- innovative active/passive noise control based on advanced computational models;
- integrated approach to comfort, entertainment and creation of flexible home/office environment.

More research is required before the technologies developed within SEAT could be effectively incorporated into the aircraft Cabin.